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G1A
G1R
G4A
Selected US specifications from IPC sub-class G01F

(54) Flowmeter calibration

(57) The calibration includes the steps of:

obtaining desired master values of a flow meter output variable for first known flow rates 3;

establishing, from the master values, a master plot of output variable against flow rate 4;

obtaining actual values of the output variable of the meter for second known flow rates through the meter 1; and

determining coefficients of a calibration polynomial function 11, which establishes a relationship between flow rates and values of the output variable.

When the flow meter to be calibrated uses a rotary variable differential transformer RVDT, the method includes the further steps of:

multiplying each first known flow rate by a scale factor to obtain a corrected flow rate; and

establishing a second master plot 17, by plotting against master values of output variable against corrected flow rate and by linear interpolation between the points so obtained.

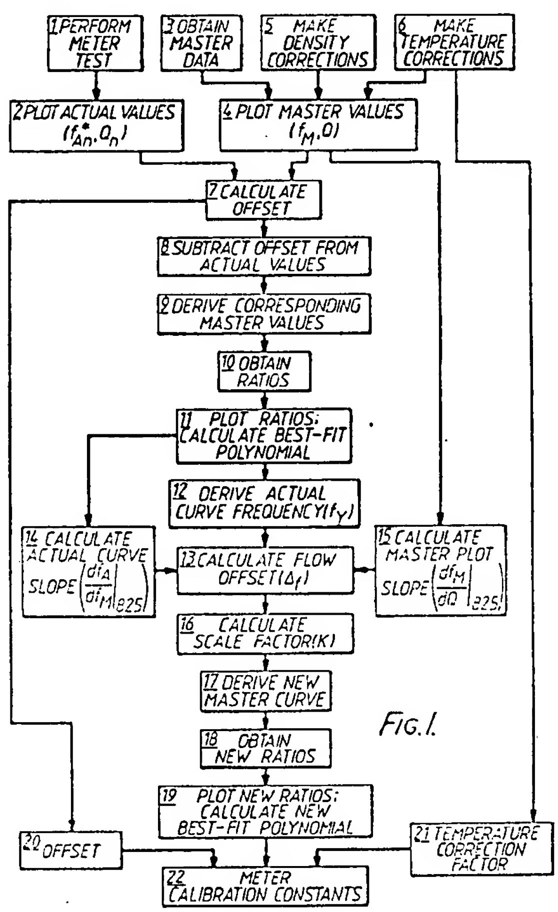

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

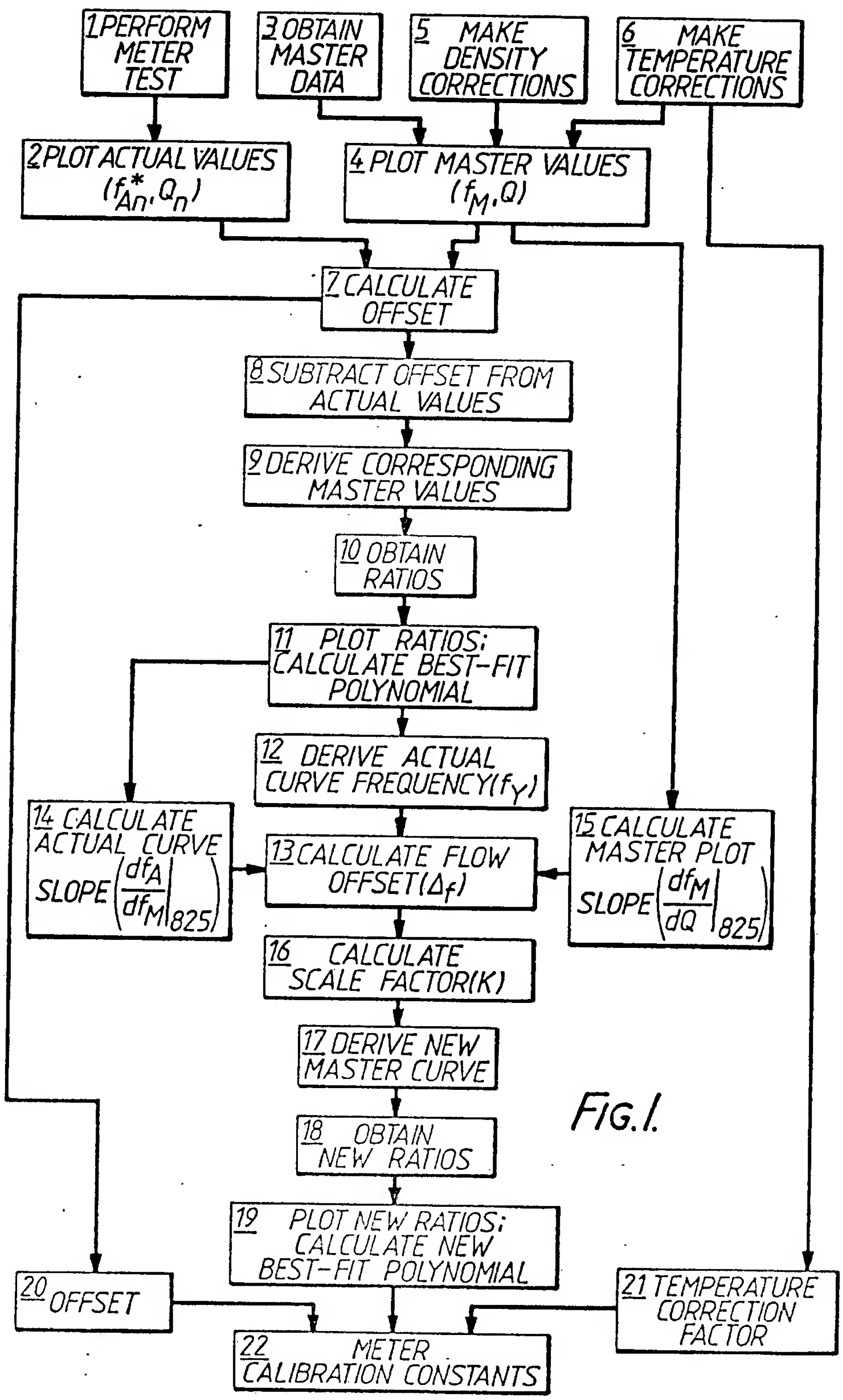
1 PERFORM METER TEST
3 OBTAIN MASTER DATA
5 MAKE DENSITY CORRECTIONS
6 MAKE TEMPERATURE CORRECTIONS
2 PLOT ACTUAL VALUES (f^*_{An}, Q_n)
4 PLOT MASTER VALUES (f_M, Q)
7 CALCULATE OFFSET
8 SUBTRACT OFFSET FROM ACTUAL VALUES
9 DERIVE CORRESPONDING MASTER VALUES
10 OBTAIN RATIOS
11 PLOT RATIOS; CALCULATE BEST-FIT POLYNOMIAL
12 DERIVE ACTUAL CURVE FREQUENCY(f_Y)
14 CALCULATE ACTUAL CURVE SLOPE $\left(\frac{df_A}{df_M}\bigg|_{825}\right)$
13 CALCULATE FLOW OFFSET(Δ_f)
15 CALCULATE MASTER PLOT SLOPE $\left(\frac{df_M}{dQ}\bigg|_{825}\right)$
16 CALCULATE SCALE FACTOR(K)
17 DERIVE NEW MASTER CURVE
18 OBTAIN NEW RATIOS
19 PLOT NEW RATIOS; CALCULATE NEW BEST-FIT POLYNOMIAL
20 OFFSET
21 TEMPERATURE CORRECTION FACTOR
22 METER CALIBRATION CONSTANTS

FIG. 1.

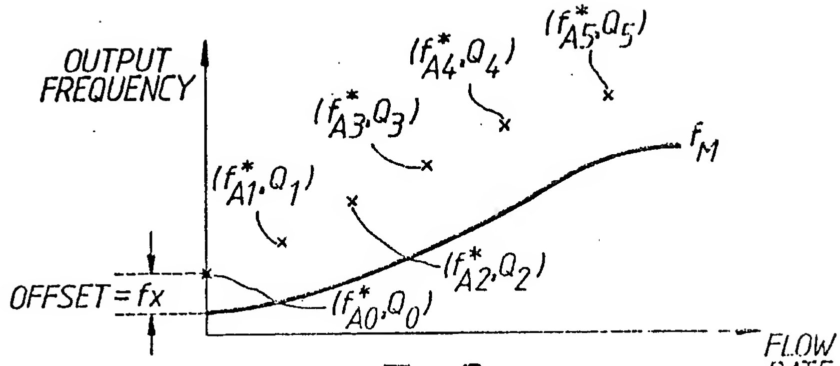

FIG. 2.

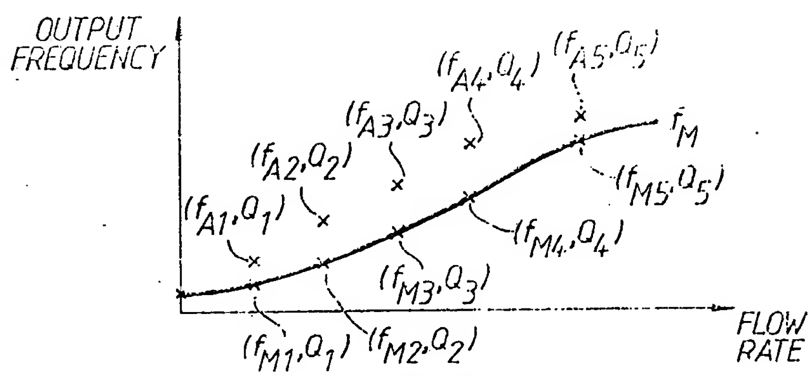

FIG. 3.

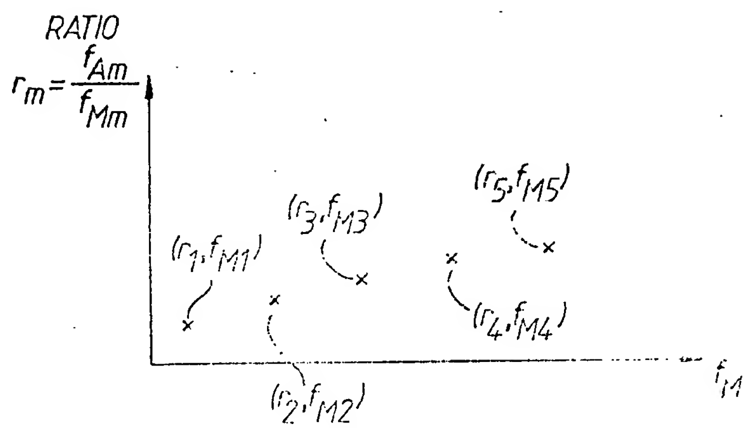

FIG. 4.

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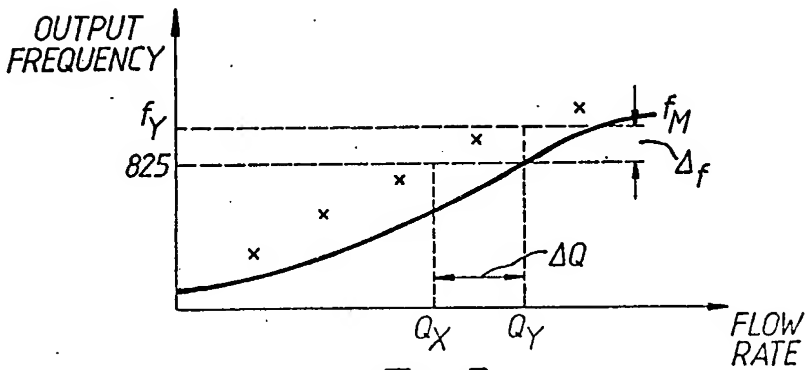

FIG.5.

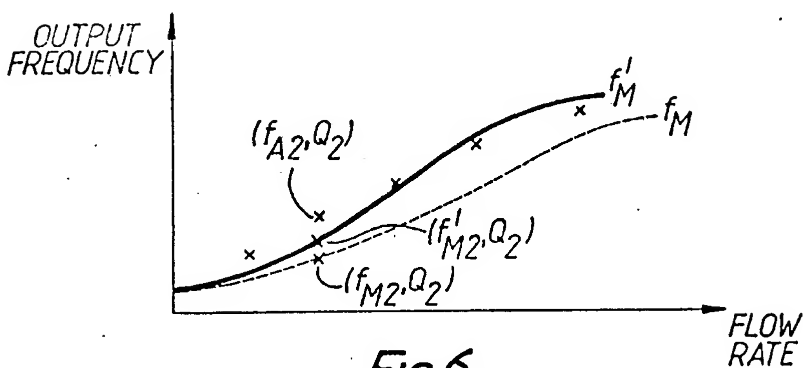

FIG.6.

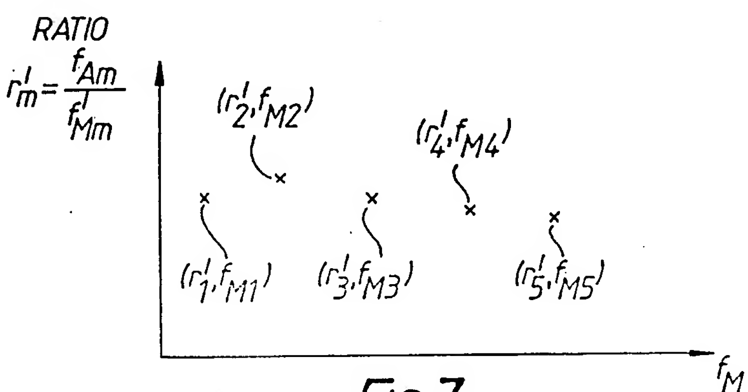

FIG.7.

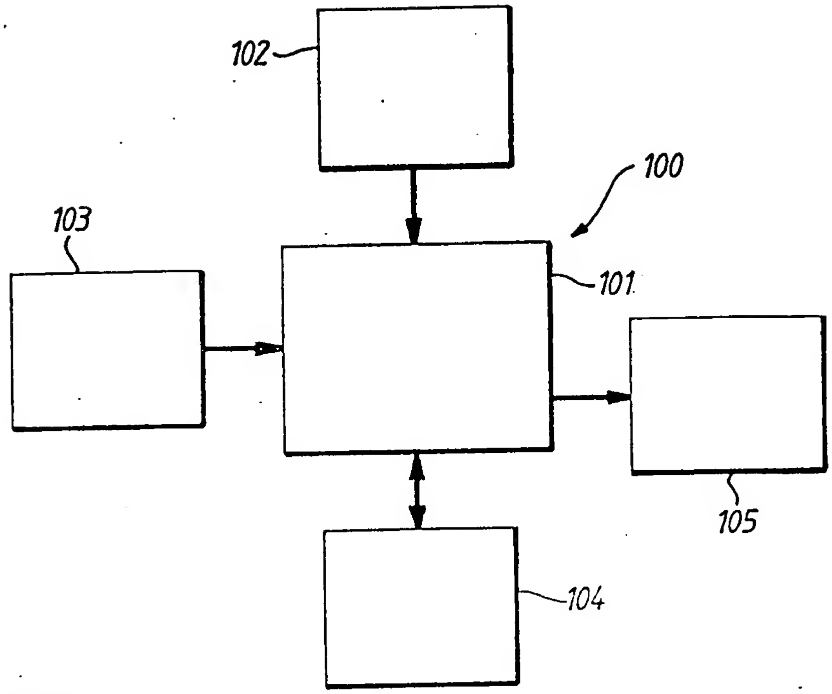
102
100
103
101
105
104

FIG.8.

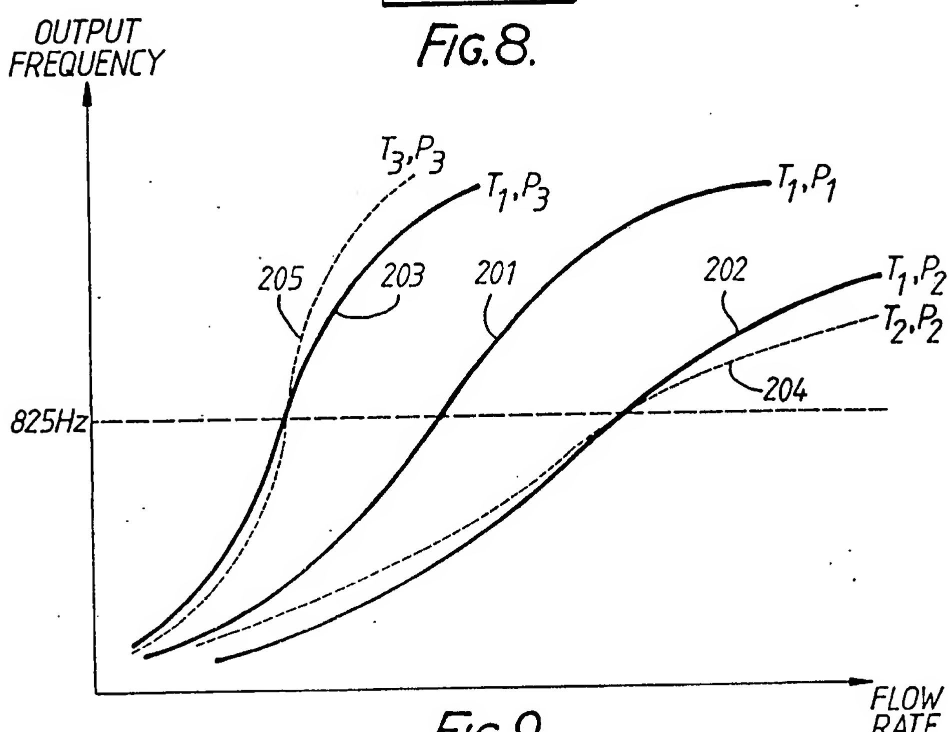
OUTPUT FREQUENCY
T_3,P_3
T_1,P_3
T_1,P_1
205
203
201
202
T_1,P_2
T_2,P_2
204
825Hz
FLOW RATE

FIG.9.

SPECIFICATION

Flowmeter calibration

This invention relates to a method and apparatus for calibration of a flowmeter and, more particularly, though not exclusively, to a method and apparatus for calibration of a flowmeter containing an RVDT (rotary variable differential transformer) and to flowmeter arrangements incorporating flowmeters calibrated by such methods and apparatus.

There are known many different kinds of flowmeter, devices which may be inserted into a fluid-carrying channel to measure the rate of flow of fluid along that channel. The known flow meters may be made with great precision; however, each device will have a unique output characteristic. Although every effort will be made during manufacture of the device to produce a meter, the output characteristic of which corresponds exactly with a standard output characteristic used for calibration purposes, it is often difficult, and always expensive, to improve the manufacturing tolerances beyond certain standards of accuracy.

One attempt to overcome this problem is described in British Patent No. 2,116,720. In this patent, there is described a flow rate sensor which has an in-built data storage means, in which are stored a number of adjustment factors. Each adjustment factor is assigned to one particular section in the range of flow rates which may be measured by the meter, and a measurement of flow rate is obtained from the sensor by multiplying the meter output by the appropriate adjustment factor.

However, this known device has the disadvantages, firstly that the increase in accuracy of the output is not particularly large, as each adjustment factor, although utilised over a whole range of flow rates, may be accurately applicable at only one point in that range; and, secondly, that the data storage means, once programmed, may be used with one flow meter only, and it is not possible to re-program the storage means for use with another flow meter.

The present invention seeks to provide a method of calibration of a flow meter which, although requiring tests to be made on the flow meter at only a small number of flow rates, can provide a relatively accurate output reading of flow rate. The invention seeks to further to provide a device, for use with a calibrated flow meter, the device being able to be programmed with calibration constants appropriate to the particular flow meter, to allow an acceptably accurate measurement of flow rate to be obtained using an output signal from that flow meter.

According to one aspect of the present invention, there is provided a method of calibration of a flow meter comprising the steps of:

obtaining desired master values of an output variable of the flow meter for a plurality of first known flow rates through the meter;

establishing, on the basis of the master values, a master plot of the output variable against the flow rate;

obtaining actual values of the output variable of the flow meter for a plurality of second known flow rates through the meter; and

determining coefficients of a calibration polynomial function, the calibration polynomial function establishing a relationship between flow rates and values of the output variable.

Preferably, the method comprises the additional steps of:

multiplying each first known flow rate by a scale factor to obtain a corrected flow rate; and

establishing a second master plot, by plotting first master values of the output variable against corrected flow rate and by linear interpolation between the points so obtained,

wherein the scale factor is chosen such that, for a null flow rate, the value of the output variable obtained from the second master plot is approximately equal to an offset-reduced actual value of the output variable obtained from the meter being calibrated and to a null value of the output variable, at which the value of the output variable is known to be largely independent of the temperature of fluid passing through the meter.

According to a second aspect of the present invention, there is provided a device for calculating flow rates through a flow meter, the device comprising:

storage means, containing master values of an output variable obtained from a standard meter at known flow rates through the standard meter;

processing means, programmed to calculate, on the basis of input values of an output variable from the flow meter and input calibration polynomial coefficients of the meter, the flow rate through the meter;

input means, for inputting to the processing means values of an output variable from the flow meter and calibration polynomial coefficients of the meter; and

output means, for displaying to an operator the calculated flow rate through the meter,

wherein the processing means calculates the flow rate through the meter using a polynomial expression having said polynomial coefficients and relating values of an output variable from the meter to master values of the output variable, and hence to flow rates through the meter.

For a better understanding of the present invention, and to show how it may be carried into

effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a flow-chart, showing schematically a preferred embodiment of a method according to a first aspect of this invention;

Figure 2 is a plot of output frequency against flow rate, illustrating step 7 in Figure 1;

Figure 3 is a plot of output frequency against flow rate, illustrating step 8 in Figure 1;

Figure 4 is a plot of the ratio r, which is defined below, against master value of frequency, illustrating step 10 in Figure 1;

Figure 5 is a plot of output frequency against flow rate, illustrating steps 12 to 16 in Figure 1;

Figure 6 is a plot of output frequency against flow rate, illustrating step 17 in Figure 1;

Figure 7 is a plot of the ratio r′, which is defined below, against master value of frequency, illustrating step 18 in Figure 1;

Figure 8 is a schematic representation of a device according to a second aspect of this invention; and

Figure 9 is a plot, for a flowmeter including an RVDT, of output frequency against flow rate at different temperatures and pressures.

Figure 1 is a schematic representation of a method of calibration of a flow meter, which in this embodiment is specifically intended to be used for the calibration of a flowmeter which includes a rotary variable differential transformer (RVDT). Such a flow meter typically provides output pulses, at a frequency which varies with the rate of flow of fluid through the meter, and it is this output frequency which is the measured variable. Although the frequency increases with increasing flow rates, this variation is generally non-linear.

The first stage in the calibration procedure is to perform a test on the meter which is to be calibrated. This step, designated in Figure 1 by the reference numeral 1, comprises passing through the meter which is to be calibrated a fluid, for example water, at a number of known flow rates, and measuring the output frequency from the meter at these flow rates. The values of output frequency thus obtained, $f^*_{A1},\ldots, f^*_{An}$, are then plotted, step 2 in Figure 1, against the corresponding flow rates $Q_1,\ldots, Q_n$.

This plot is now compared with a further plot, derived from master data. The master data are the values of the output frequency obtained from a standard meter in tests using, for example, steam at a pressure of 8 bar gauge at a number of known flow rates. These values are then stored, and are used in the calibration of each meter. The master data are then corrected for the different densities of the steam and the water used in the meter test, step 5 in Figure 1, and for the different temperatures of the steam and the water, step 6 in Figure 1. These corrections must take into account the different output frequencies obtained at a given flow rate which result from the different fluid densities and the temperature-dependent output characteristics of the meter respectively. When the corrections are taken into consideration, the master data can be used to obtain a plot of the master values of output frequency against flow rate. The number of known flow rates is chosen such that it is possible to interpolate linearly between these master values to obtain a master plot, of the desired accuracy, over the whole of the desired range. The chosen number of known flow rates will depend on the desired accuracy and on the linearity of the flow curve, but in one illustrative embodiment of the invention, measurements are made at 33 known flow rates. It should also be borne in mind that increasing the number of flow rates will, while increasing the accuracy of the master plot, place a greater burden upon the software which is intended to be used in calibrating the meter. Figure 2 shows a plot, on the same axes, of the actual values and of the master curve obtained by linear interpolation between the master values. These superimposed plots are now used to calculate the offset frequency f_x, step 7 in Figure 1. The offset f_x is obtained by subtracting from the actual value of output frequency f^*_{A0} obtained at zero flow rate the master value of output frequency f_m which corresponds to a zero flow rate.

The offset frequency f_x is now subtracted from each of the actual frequency values $f^*_{A1},\ldots,f^*_{An}$, to obtain the offset-corrected actual values $f_{A1},\ldots,f_{An}$, which is the step designated by the reference numeral 8 in Figure 1, to obtain the plot shown in Figure 3.

The next step, designated by the reference numeral 9 in Figure 1, is to obtain master values of the output frequency at the flow rates $Q_1,\ldots, Q_n$. These output frequencies $f_{M1},\ldots, f_{Mn}$ may simply be read off the master plot.

Then, step 10 in Figure 1, the ratios of the offset-corrected actual frequency to the master frequency are calculated at each flow rate $Q_1,\ldots, Q_n$.

These ratios $r_1=f_{A1}/f_{M1},\ldots, r_n=f_{An}/f_{Mn}$ are then plotted against corresponding values of the master output frequency $f_{M1},\ldots, f_{Mn}$, and the resultant plot is shown in Figure 4. Then, step 11 in Figure 1, a regression analysis technique is used to determine the coefficients of a least squares best-fit polynomial relating the ratio r to the master output frequency f_M.

In the example shown in Figures 2 to 4, frequency measurements are made at zero flow and at five other known flow rates, and thus the plot of Figure 4 has five points. However, it is possible to achieve satisfactory results by taking measurements at four known flow rates, and in this situation, the best-fit polynomial may advantageously be chosen to be a quadratic relation-

ship, with three unknown coefficients, thus ensuring a level of redundancy in the measurements made, so that the accuracy of the calibration may be assessed. Thus, in view of the possibility of an inaccurate measurement, the curve fit error may be calculated at each calibration point and the calibration rejected if any error is greater than a predetermined amount, for example 1%, at my point.

Thus : $r = f_A/f_M = A' + B'.f_M + C'.f_M^2$
or : $f_A = A'.f_M + B'.f_M^2 + C'.f_M^3$

Thus, once the calibration polynomial coefficients A', B', C' and the offset frequency f_x are known, values of the output frequency obtained at unknown flow rates may be processed in accordance with the calibration polynomial to produce outputs equivalent to the master value which would be obtained from the standard meter at that flow rate, and hence an accurate measure of that flow rate.

Thus, there is provided a method of calibration, which may be used in conjunction with any type of flow meter which produces an analogue output signal which varies with the rate of flow of fluid through the meter. However, the method can be refined further, as described below, if more is known about the characteristics of the particular type of meter which is to be calibrated.

For example, a flow meter which measures flow using a rotary variable differential transformer is slightly influenced by changes in the temperature of the fluid, the flow rate of which is to be measured, although this influence is a second order effect only.

That is, equal flow rates of a fluid at different temperatures will produce different output signals from the flow meter. It is possible, however, to reduce the inaccuracy resulting from this feature by using the method of calibration shown schematically in Figure 1. It is known that one particular flow meter incorporating the RVDT, described in greater detail in British Patent Application No. 8620931 has an output characteristic which is largely independent of temperature at an output frequency corresponding to the position of symmetry when the rotating armature is midway between the primary and secondary transformer coils, and this information may be used to reduce the inaccuracy mentioned above, by using the fact that the actual flow rate through the meter being calculated that produces that output frequency will be independent of temperature. In the illustrated embodiment, the output frequency corresponding to the position of symmetry is 825Hz.

Thus, there is derived a new master curve from the master curve mentioned previously, and the actual data, obtained from the test on the meter which is to be calibrated, are then related to this new master curve.

The new master curve is derived from the old master curve, which was formed by plotting the points $(f_{M1}, Q_{M1}),\ldots, (f_{M33}, Q_{M33})$, by multiplying each flow rate Q_M by a scale factor K, chosen such that the new master curve has approximately the same flow rate at 825Hz as the meter being calibrated.

The method of calculation of the scale factor K is described below with reference to Figure 5, in which are plotted the same points as Figure 3. The flow rate corresponding to an output frequency of 825Hz on the master curve is designated by Q_y, while Q_x designates the flow rate corresponding to an output frequency of 825Hz from the meter being calibrated. Then, ΔQ is given by $(Q_y - Q_x)$. The actual output frequency corresponding to a flow rate Q_y is designated by f_y, and $(f_y - 825) = \Delta f$ (step 13 in Figure 1).

The scale factor K is given by:

$$K = \frac{Q_Y - \Delta Q}{Q_Y},$$

where Q_y is taken from the master plot obtained previously and ΔQ is obtained from:

$$\Delta Q \simeq \frac{dQ}{df_A} . \Delta f,$$

where $\frac{dQ}{df_A} = \frac{dQ}{df_M}_{825} . \frac{df_M}{df_A}_{825}$,

$\frac{dQ}{df_A}$ being the inverse of the slope of the actual value against flow rate "curve" at a flow rate corresponding to a master plot frequency of 825Hz;

$\frac{dQ}{df_M}_{825}$ being the inverse of the slope of the master plot at a frequency of 825Hz (step 15 in Figure 1); and

$\frac{df_M}{df_{A825}}$ being obtained from the polynomial relationship between f_A and f_M derived earlier, (step 14 in Figure 1).

$$f_A = A'.f_M + B'.f_M^2 + C'.f_M^3,$$

$$\frac{df_A}{df_M} = A' + 2.B'.f_M + 3.C'.f_M^2, \text{ and}$$

$$\frac{df_A}{df_M}_{825} = A' + 2.825.B' + 3.(825)^2.C'$$

$\Delta f = f_y - 825$, and f_y is also obtained also using the previously derived polynomial relationship.

Thus, $f_y = A'.825 + B'.(825)^2 + C'.(825)^3$, (step 12 in Figure 1)

$$\text{Therefore, } \Delta Q = \frac{(f_Y - 825)}{\left.\frac{df_M}{dQ}\right|_{825} \left.\frac{df_A}{df_M}\right|_{825}},$$

enabling K to be calculated from $K = \frac{Q_Y - \Delta Q}{Q_Y}$

as mentioned above, designated in Figure 1 as step 16.

Naturally K could be calculated in many different ways, most simply by obtaining a value for Q_x, and hence Q, by linearly interpolating between two points of the plot f_A against Q to obtain a flow Q_x corresponding to f_A = 825Hz. However, this latter method only uses two of the pieces of calibration data, and is thus more likely to give an inaccurate value for K as a result of inaccuracies in the measured data.

Thus, as mentioned previously, a new master curve, shown in Figure 6, is obtained, step 17 in Figure 1, the flow rate corresponding to 825 Hz on the new master curve being the same as the flow rate through the meter being calibrated corresponding to an output frequency of 825Hz.

The next step, designated by the reference numeral 18 in Figure 1, is similar to step 10 described previously. The "new master" frequencies $f'_{M1}, \ldots, f'_{Mn}$, corresponding to the flow rates

$Q_1, \ldots, Q_n$, are read off the new master curve. Then, the ratios of the actual output frequencies $f_{A1}, \ldots, f_{An}$ to these "new master" frequencies at these flow rates are calculated.

Then, step 19 in Figure 1, these new ratios, given by $r'_m = f_{Am}/f'_{Mm}$, are plotted against corresponding values of the first master frequency, and a least squares best-fit relationship is derived.

This relationship, as mentioned previously, might be chosen to be quadratic :

$$r' = \frac{f_A}{f'_M} = A + B.f_M + C.f_M^2 \qquad \text{(i)}$$

Therefore, once the calibration coefficients A, B, C and K, and the offset frequency f_x have been calculated, as described herein, during the calibration of a meter, any value of output frequency f_A measured at an unknown flow rate can be related to a corresponding master frequency value f_M, and hence to a flow rate.

It has been found that the accuracy of an RVDT meter can be increased by a factor of 10 by using a re-calibration technique as described above, even though, during the calibration, frequency measurements are made at only four known flow rates.

The improved accuracy arises largely because the final relationship which is obtained (equation (i) above) is largely linear. That is to say, the ratio r' is largely constant; and thus independent of f_M, and so a quadratic equation may be fitted to the plot of Figure 7 with a high degree of accuracy.

If measurements of frequency are made at more known flow rates, then the polynomial may be chosen to be of a higher order, ensuring even greater accuracy, although this increased accuracy, which will eventually be limited by the accuracy to which the "known" flow rates can actually be measured, and the accuracy of the frequency measurements, must be balanced against the increased time necessary for calibration, when deciding how many measurements are to be made.

One advantage of the method according to the first aspect of the present invention is that the results of the calibration consist of a relatively small number of calibration constants. For example, in the method described above, there are only five such constants, the polynomial coefficients A, B, C the scale factor K, and the offset frequency f_x, and this set of constants is unique to the particular meter which is calibrated. Once they have been calculated, therefore, these constants may be used to obtain accurate values of the flow rate corresponding to any output frequency signal obtained from the meter at an unknown flow rate.

Thus, this invention also relates to the provision of a device which, when the calibration constants for a meter are input into that device, is capable of providing output readings of flow rate on the basis of input values of frequency and, if required, temperature. (It should be noted that this operation will take place separately from the calculation of the calibration constants, which will be done during the manufacturing stage of the meter itself. The calculation of these constants may be performed by any suitably programmed computer, using the method described above).

Figure 8 shows, schematically, an embodiment of a device for calculating the flow rates on the basis of the input calibration constants and measured values of output frequency. The device 100 includes a processing unit 101, such as an RCA 1805, which takes input data from an EPROM 102 and a key-pad 103. In the EPROM 102 are stored the master data, obtained as described previously from tests on a standard meter at known flow rates, the master data including measurements of temperature and output frequency at the known flow rates, and the EPROM also being programmed with values of the specific enthalpy and density of the saturated vapour and liquid, h_g, h_{lg}, ρ_g, ρ_l, and the pressure of saturated steam at each temperature.

The key-pad 103 is used to input into the processing unit 101 the values of the calibration constants A, B, C, and f_x and, if used K, plus information about the size of the meter. This information is necessary because, it will be appreciated, two meters might produce equal output frequencies at greatly differing flow rates if they are of different sizes, since the output frequency depends upon the rotation of a member located in the fluid flow.

Then, in use of the device to obtain flow rate measurements, input signals from a flow meter (that is, measurements of output pulse frequency and fluid temperature) are input into the processing unit 101, where correction for the temperature and the dryness fraction of the steam passing through the meter are made. The corrected frequency measurements are then compared with data stored in the RAM 104. When the flow rate through the meter has been determined, this is then displayed on the sixteen character alphanumeric display 105.

Figure 9 shows the frequency output characteristic for the RVDT flow meter at different values of temperature and pressure; knowledge of this characteristic is used when correcting the readings of the meter for changes in temperature in pressure. The line 201 shows the output characteristic at a temperature T_1 and pressure P_1, while the line 202 shows the output charac-

teristic at the same temperature T_1 but a higher pressure P_2 and line 203 shows the output characteristic at that temperature T_1 but a lower pressure P_3. At constant temperature, the pressure compensation factor is proportional to the square root of the fluid density at the pressure of interest.

The correction for temperature differences, however, cannot be applied so simply. In Figure 9, the line 204 shows the output characteristic of the RVDT flow meter at the pressure P_2 and a temperature T_2 higher than T_1, while line 205 shows the output characteristic at a pressure P_3 but a temperature T_3 higher than T_1. Thus, it can be seen that, on opposite sides of the line 201, which in this case is at a pressure of 8 bar gauge, increases in temperature cause rotations of the output characteristic in opposite directions. These rotations take place about points on the curves corresponding to output frequencies of 825Hz, which, as mentioned previously, is the frequency at which changes in temperature have little effect on the output characteristic.

It is an advantage of the present invention that it is necessary to provide only one processing device, which may, at different times, be used in conjunction with several different flow meters, simply by re-programming the processing device with the values of A, B, C and f_x and, if used, K, appropriate to the meter in use. Moreover, using the key-pad 103, the device may be re-programmed simply by entering the appropriate coefficients. The re-programming can be carried out on site, and there is no need for a skilled operator to effect the re-programming.

The calibration of each meter is also easily achieved, as it is necessary to carry out tests at a relatively small number of known test flow rates. Thus, if it is required to re-calibrate a meter, the output characteristic of which may vary with extended use of the meter, this may also be done quickly. It is anticipated that, after calibration, a meter will be marked, to indicate the calibration coefficients appropriate to that meter. Thus, a user of the apparatus may, when changing from the use of one meter to another, easily identify the coefficients with which the processing device is to be programmed.

CLAIMS

1. A method of calibration of a flow meter comprising the steps of:
obtaining desired master values of a flow meter output variable for a plurality of first known flow rates;
establishing, on the basis of the master values, a master plot of the output variable against the flow rate;
obtaining actual values of the output variable of the flow meter for a plurality of second known flow rates through the meter; and
determining coefficients of a calibration polynomial function, the calibration polynomial function establishing a relationship between flow rates and values of the output variable.

2. A method of calibration as claimed in claim 1, wherein the actual values of the output variable are obtained by:
causing a calibration fluid, for example water, to flow, at a plurality of second known flow rates, through the meter being calibrated, and, at each second known flow rate, measuring the value of the output variable.

3. A method of calibration as claimed in claim 2, wherein when the actual values of the output variable are being obtained, the temperature of the calibration fluid at each second known flow rate is measured, and wherein the desired master values of the output variable are obtained by:
passing a metering fluid, for example steam, through a previously calibrated meter at a plurality of first known flow rates of metering fluid;
measuring the values of the output variable obtained at the plurality of first known flow rates of metering fluid; and
converting the values of the output variable at known flow rates of metering fluid to values of the output variable at known flow rates of calibration fluid by taking into consideration the temperatures and the densities of the calibration fluid and the metering fluid at the pluralities of first and second known flow rates respectively.

4. A method of calibration as claimed in any preceding claim, wherein the master plot of the output variable against the flow rate is established by plotting points corresponding to the master values of the output variable at the plurality of first known flow rates, and by linear interpolation between those points.

5. A method of calibration as claimed in any preceding claim, wherein
the actual value of the output variable of the flow meter is obtained at zero flow;
an offset value is obtained by subtracting from the actual value of the output variable at zero flow the value of the output variable at zero flow given by the master plot; and
the offset value is subtracted from the actual value of the output variable to give an offset-reduced actual value at each second known flow rate.

6. A method of calibration as claimed in claim 5, wherein, for each second known flow rate except zero:

the first master value of the output variable is obtained from the first master plot; and

the ratio of the offset-reduced actual value to the first master value is calculated; and wherein a first best-fit polynomial is calculated relating the values of the ratio so obtained to the corresponding first master values of the output variable, whereby values of the output variable obtained at unknown flow rates may be identified with corresponding respective first master values of the output variable and hence with corresponding respective flow rates.

7. A method of calibration of a flow meter as claimed in any preceding claim, the method comprising the additional steps of:

multiplying each first known flow rate by a scale factor to obtain a corrected flow rate; and

establishing a second master plot, by plotting first master values of the output variable against corrected flow rate and by linear interpolation between the points so obtained,

wherein the scale factor is chosen such that, for a null flow rate, the value of the output variable obtained from the second master plot is approximately equal to the offset-reduced actual value of the output variable obtained from the meter being calibrated and to a null value of the output variable, at which the value of output variable is known to be largely independent of the temperature of fluid passing through the meter.

8. A method of calibration of a flow meter as claimed in claim 7, further comprising the additional steps, for each second known flow rate except zero, of:

obtaining a second master value of the output variable from the second master plot; and

calculating the ratio of the offset-reduced actual value to the second master value;

wherein a second best-fit polynomial is calculated, relating the values of the ratio so obtained to the corresponding second master values of the output variable, whereby values of the output variable at unknown flow rates may be identified with corresponding respective second and first master values of the output variable and hence with corresponding respective flow rates.

9. A device for calculating flow rates through a flow meter, the device comprising:

storage means, containing master values of an output variable obtained from a standard meter at known flow rates through the standard meter;

processing means, programmed to calculate, on the basis of input values of an output variable from the flow meter and input calibration polynomial coefficients of the meter, the flow rate through the meter;

input means, for inputting to the processing means values of an output variable from the flow meter and calibration polynomial coefficients of the meter; and

output means, for displaying to an operator the calculated flow rate through the meter,

wherein the processing means calculates the flow rate through the meter using a polynomial expression having said polynomial coefficients and relating values of an output variable from the meter to master values of the output variable, and hence to flow rates through the meter.

10. A method of calibration of a flow meter, substantially as herein described with reference to Figures 1 to 7 of the accompanying drawings.

11. A device for calculating flow rates through a flow meter, substantially as herein described with reference to Figure 8 of the accompanying drawings.

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